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ABSTRACT

The use of quantitative decision making tools provides the decision maker with a range of alternatives among which to decide, permits acceptance and use of the optimal solution, and decreases risk. Training line administrators in the use of these tools can help school business officials obtain reliable information upon which to base district decisions. This chapter of "Principles of School Business Management" opens by discussing the essentials of the problem-solving process, including the definition of problems and the development of models that will permit effective testing of proposed solutions to problems. Special attention is paid to decision logic tables and the importance of mathematical techniques. The chapter then describes the characteristics and application of linear programming, particularly in relation to resource allocation. The influence of risk factors on decision making is reviewed next, and the value and applications of decision trees are analyzed. The use of deterministic models in inventory control is the chapter's next topic; the technique called Economic Order Quantity is stressed. The chapter concludes with an examination of Multi Criteria Decision Making, a tool used when several factors affect decisions. Ten sources are cited in footnotes, and 23 tables illustrate application of the techniques discussed. (PGD)

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Quantitative Decision Making

Grover H. Baldwin

In recent years there has been an increased move for accountability on the part of educators. Demands by the public have included the more effective and efficient use of resources. These demands are evidenced through the limiting of financial resources via rejection of budgets and the increasing demands for excellence in education by various citizens and taxpayer groups. School business administrators have turned to cost benefit and cost effective/efficient models and techniques in order to provide quality educational services and contain costs. These quantitative methods provide a much needed framework in which the school business administrator can answer the basic economic decisions facing the district—what is the best course of action for the proffered sources.

These techniques have proved helpful not only in increasing the rate of return for budgeted dollars, but also in the budgeting process and in analyzing materials and resources. While benefit/effectiveness and efficiency methods are not the sole means on which to base decisions, they permit surveillance of programs and thus provide a means to improve them. These methods also provide comparisons among programs competing for scarce resources and permit the identification of problem areas.

The need for more effective decision making and the potential use of quantitative decision-making tools has come from the public's demand that schools be accountable for their actions while optimizing their resources. As Gruber and Mohr indicate:

> There is a growing demand for accountability in a sophisticated donor community, motivated in part by the generally poor economic environment. This provides the impetus for the adoption of well-known business concepts so that nonprofit organizations may use their dwindling funds more effectively. Administrators and boards of directors of nonprofit organizations will be faced with increasingly severe competition for time, money and management skills as the nonprofit sector becomes more cost conscious.[1]

Within this rapidly changing environment, organizations which continue to react as if they operate within a stable environment, ultimately will be forced to change in a dramatic and revolutionary manner, i.e., to adopt an entrepreneurial management style. This calls for recognition of the limitations of the reactive style of management which lets events control the organization and a change to a management style that detects early disturbances and meets the challenges of the environment before they become devastating. It also means that the management of the district must utilize techniques that are associated with the economic decision-making process of optimization, rather than the use of satisfying needs as is currently used in nonprofit organizations.

Satisfying implies the acceptance and use of the first "best" solution to the problem. Optimization involves the more detailed examination of the problem and then the application of the best solution to the problem. Typically, educational and other nonprofit organizations have opted to satisfy on a case-by-case basis as they have been faced with various populations and interest groups that all demand different results. There now appears to be a movement toward the consolidation of the various interest groups centered around the single economic question of achieving the greatest return on their investment. Thus, the argument that the public sector is vastly different from the private, and hence could not optimize their solutions and decisions, falters in light of recent and growing demands.

Quantitative decision-making tools that have long been part of the private sector decision-making process, while not guaranteeing perfect solutions, do provide the basis for rational decisions that permit greater analysis of the various aspects of the issues and programs under consideration. Further, they provide the flexibility and sensitivity to the nuances of various decision structures. While the older forms of quantitative tools—including linear programming, PPBS, CPM and Pert—still have application in the changing environment, the techniques of decision logic tables, decision tree analysis, economic order quantity and multi-criteria analysis now serve the management of school districts. At the same time, use of microcomputers, with their capacity to utilize these techniques with great speed while handling greater amounts of information, facilitate the use of these techniques by the school business administrator. The school business administrator now can concentrate on problem identification and selection of the optimal solution, while the computers handle the complex and time-consuming computations.

This is not to imply that the computer and the techniques alone will provide the solution. The purpose of quantitative decision-making tools is, and always will be, analysis of information regarding the true nature of the issue to permit the individual decision maker to render the best decision for the organization. The use of these techniques provides the decision maker with a range of alternatives and permits the acceptance and use of the optimal solution, and decreases the risk and uncertainty facing the individual decision maker. The information generated by these techniques provides a firm base, within the realm of probability and uncertainty, on which to base decisions. Whether these techniques will dehumanize the decision-making process and reduce it to a mechanistic, totally rational and unfeeling process, depends solely on the individual using the processes.[2] Inasmuch as school business administrators operate within an open decision-making environment, they will be able to incorporate these processes.

How do these techniques affect the role of the school business administrator? First, it should be noted that it appears that the school business administrator is the individual within the school administration who is best suited to use these techniques, since the training in financial analysis and decision-making received by these individuals lends itself to the quantitative decision-making process. Thus, the school business administrator is the logical person to oversee the implementation and management of these processes. A second function that the school business administrator has with respect to these techniques is to assist other management personnel to effectively apply these processes to their own decision-making activities.

While the private sector initially assigned these tools and processes to specialists within the organization, known as "strategic planners," recent reports indicate that strategic planning staffs have been, and are being, reduced in favor of increasing the involvement of line managers in the decision-making process.[3] Within the field of education, there is ever increasing demand for school site budgeting, the use of management by objectives and accountability in general by building principals and central office personnel. Training of such personnel in the effective use of these techniques would greatly support managerial effectiveness of school district operations. Thus, the school business administrator's knowledge of the problem resolution techniques that are most appropriate for education, the application of these techniques via microcomputer technology and the transmitting of this information and skills to the line management are a crucial part of the school business administrator's function.

Problem Finding, Models and Problem Solving

The beginning of the process of solving problems lies in the development and refinement of the problem itself. While the school business administrator may be accustomed to dealing with crises and resolving issues and problems on a day-to-day basis, the essence of successful utilization of quantitative decision-making tools lies in the establishment of the true problem. This is a creative, challenging and thought-provoking process which calls on management, either singularly or as a team, to identify the elements which caused, created and control the issues that are identified as problems.

The most common approach to problem-identification is the "after the fact method" which focuses on causes of problems within the organization. The preferred approach is that of identifying the elements, variables, constraints, risks and uncertainties that face the organization and then establishing the relationship among these elements which contribute to the problem to be solved.[4] This approach, which keeps the management dealing with the real issues of the problem and not merely the symptoms, requires the adoption of a perspective that permits creative and divergent thinking.

To successfully use the process, management must recognize its role as the catalyst for effective decision making within the district. This first calls on the management to have a clear picture of what they desire and where the organization is going. Without this clear objective or goal the organization will continue to merely react to the process and not proactive in its management which increasingly is called on to meet the demands of a varied public.

The process is not a straight line, lock-step process, but rather an ebb and flow of creativity that leads beyond the symptoms to the problem. The decision maker goes through various stages in development and refinement of the problem. First, the individual establishes the global concerns of the organization by answering the question, "What are the the specific elements that constitute the goals and objectives of the organization?" To answer this, the manager needs to: 1) examine both the internal and external environments which affect the organization; 2) identify the demands of individuals and groups within these environments; and 3) determine the effect and relationship between these two sectors on the organizational goals and objectives. The internal environment includes the personnel, the organi-

zational make-up and the circumstantial elements and constraints within the organization itself. The external environment includes the patrons of the district and the competition from both the private sector educational establishments and the neighboring public school districts.

The second step is to identify the variables—independent, dependent, confounding or extraneous—and the constraints that are part of the situation and their relationship. Through careful examination and critical evaluation of the information which confronts the individual, certain variables are eliminated and others used as part of the problem-finding process. This step includes the sharing of the ideas and variables with others on the management team, and not only assures that the variables are germane to the issue (i.e., not merely symptoms), but also that they are precisely stated and provide for a range of applicability and usefulness.

After locating the variables, the decision maker creatively combines them to examine their effects on each other and ultimately establish a set of interrelationships as the true problem. Identification of significant interrelationships is the third step. Once a set of variables and effects has been identified, the individual moves to the fourth step, the establishment of solutions of the problem.

In establishing the possibilities from which the solution will be selected, the individual must identify a *complete set of choices.* This is a part of the problem-finding process that demands creativity. All opportunities, possibilities and choices must be identified. There are limitations to the process due to the uncertainties and risks which are associated with the choices and the environment, but as nearly as possible, these uncertainties must be ascertained. In examining the possibilities, the individual must account for the conditions under which each choice would optimally solve the problem, determine the consequences of putting each choice in place and establish the criteria on which to judge the effectiveness of using each of the alternatives. This last point is directly related to the goals and objectives of the organization. These goals and objectives become the guiding principle for the decision maker in selecting from the numerous possibilities the optimal alternative to solve the problem.

What can be done about the uncertainties and the risks that face the decision maker? This is where the judgment, creativity and insight of the individual come into play. Although we cannot control all factors and while certain risks and uncertainties will remain, the individual must reduce these to the barest minimum. Based on past experience and information and the use of forecasting techniques, the decision-maker eliminates from consideration those aspects of the environment that do not significantly affect the actions to be taken. The decision maker needs to quantify the risks and uncertainties with respect to probability, and apply the probabilities to each alternative being considered in order to determine the optimal solution. In the end, however, problem resolution is a "judgment call" made with the help of a repertoire of the creative, proactive managerial tools.

Problem finding before the fact is the important function of the management team in the current and future environment. Shoennauer indicates that this process involves five activities: 1) a *change audit*—the examination of the needed changes to meet the goals and objectives of the organization; 2) a *decision audit*—the examination of the decision-making process itself and the information needed to render the decision; 3) an *implementation audit*—involving the examination of the process for the implementation of the decision; 4) a *resource audit*—the scrutiny of the resources available and needed to produce the desired consequences of the pro-

posed action to meet the goals and objectives of the organization; 5) and an *activity audit*—the step-by-step process of the decision.[5] These audits should be conducted prior to making the decision, as they will permit the decision maker to examine the effects of each viable alternative and examine it for potential failure or harm to the organization, or for not fulfilling the goals and objectives of the organization in an appropriate manner.

The question arises as to how best to complete the problem-finding process. The answer, in part, lies in the use of models. While the decision maker must be creative and use intuitive means to identify the problem, the use of a formal process including models will permit the examination and accounting of all potential variables and solutions and permit the selection of the optimal model. The individual remains the key in the entire process. The models, which are representations of reality, are merely techniques by which the individual can better utilize powers of analysis and selection in order to consider all possible choices prior to rendering a decision.

Models come in three types: *iconic*, or toy models such as children use; *analog*, or proportionate models such as a tire gauge that represents the pressure in a tire on some scale; and, the type with which we are most concerned, *mathematical* symbolic models which use mathematical notations to describe the relationships among various aspect of the environment.[6] For the decision maker the use of models assists by: 1) categorizing the various aspects of the situation; 2) permitting an inclusion of all choices; 3) identifying and thereby reducing the risks and uncertainties in the decision making, and 4) rendering data concerning the possible optimal solution given various states of nature and conditions and possible solutions. Models are used most effectively as an adjunct to the decision maker's intuitive powers and provide a formal setting in which to test possibilities against the fulfillment of the desired goals and objectives without risking loss of time, money and effort.

There are two kinds of models with which decision makers are concerned. The first is the *deterministic model* that deals with the selection of an optimal solution where all variables can be identified. Such a model could be used to make determinations concerning the number of staff needed in the next academic year, the number of textbooks needed and so on. The second type, the *stochastic model*, is used when uncontrollable factors or variables exist. It calls on the individual to use probabilities as a means to account for these factors and then to apply them to the model to render data concerning the best possible solution.

The use of models provides guidance to the individual and insight into the relationships among the variables. The use of models enhances the intuitive decision-making capabilities of the manager and the organization. The application of models can be made to both operational (day-to-day) decisions as well as to the determination of long-term goals and objectives and the implementations plans needed to accomplish these goals.

Models, however, are not always the best tools for decision makers. They are best used when they can save time, money and effort, permit more efficient management of the organization, reduce errors in decision making and implementation and promote communication among members of the management team, the staff and the public.[7] Models should not be considered for use where: there is little incentive such as in the stable environment of the nonprofit organization (although such conditions in school districts have vastly changed to a dynamic and constantly

changing environment); decisions are of a qualitative nature (although the use of multi-criteria decision-making techniques may assist in the decision process); or there is not sufficient information regarding the various aspects of the problem to permit quantification of the probabilities of the risks and uncertainties to render effective use of the model.

Effective use of models as decision-making tools requires that they be as simple as possible to use and understand. Prior to the introduction of microcomputers an argument against the use of mathematical models was based on the time-consuming aspects of completing the model. With the introduction of microcomputers and various spreadsheet programs, however, today's decision maker is already constructing and using models of a deterministic nature to forecast possible solutions and render decsions about the optimal choice to meet the district's objectives.

A case in point is the following spreadsheet program regarding budgetary concerns for a district. Using a common spreadsheet program, the school business administrator can construct a comparison set of the budget currently in operation and the proposed changes for next year. Although deterministic to a point, the school business administrator must enter probable expenditures in each category (based on information gathered about costs, negotiations and so on), and balance these against the millage for the district. The result is a millage figure that provides an indication of the needed increase or decrease. By changing the categories based on information provided through communication with the remainder of the management team, the school business administrator can quickly determine the optimum budget or provide information to the remainder of the management team concerning cost factors and areas that might be reduced to meet the level of expenditures desired.

Table 7:1 Proprosed Budget for a School District

Budget Category	Title	1984-85	1985-86	Difference $ inc./dec.	% inc./dec.
0101	Admin.	136604.00	154500.00	17896.00	1.13
0200	Instruction	1822133.00	1963300.00	141167.00	1.08
0300	Attendance	3000.00	1000.00	-2000.00	0.33
0400	Health	28584.00	30928.00	2344.00	1.08
0600	Repair	267021.00	265432.00	-1589.00	0.99
0700	Maintenance	54552.00	56423.00	1871.00	1.03
0800	Fixed	229952.00	259132.00	29180.00	1.13
1000	Stud. Act.	26265.00	24133.00	-2132.00	0.92
1200	Capital Outl.	5000.00	7000.00	2000.00	1.40
Total		2573111.00	2761848.00	188737.00	0.07

NOTE: Millage 1 mill = 32518.00 5.80 mill inc. or dec.
*1.00 plus means an increase; 00 - .99 means a decrease.

Use of the spreadsheet is fast, economical and efficient in producing the information needed by the district. Further, the use of such a model fosters open communication among the district management team. It also provides a before-the-fact consideration of alternatives, risks and uncertainties which allows the optimal solution, with individual variations, to be produced.

The nature of problem finding and the use of models is to provide the decision maker, whether an individual or a team, the opportunity to consider the ramifications of various possibilities, alternatives, risks and uncertainties on the nature of a

particular problem, and then to use this information to augment the intuitive judgment of the decision maker in finding an optimal solution.

Decision Logic Tables

Decision logic tables are models or representations of the decision-making process where conditions, actions and rules are applied in a logical manner to various states of nature that exist in the environment of the organization.[8] They should be concise, easily understood and maintained to permit their effective use by all individuals concerned with the issues. Decision logic tables provide a means by which viewers can discern the relationships between the antecedent conditions within the environment and the resulting actions and decisions taken by the school business administrator. The use of such tables is intended to: provide clarity in the explanation of decisions, help to insure their accuracy and consistency within the precedent setting trend of management, and provide for those outside the decision-making process a means by which to analyze the decisions.

Decision logic tables also serve to facilitate communications and enhance consistency of decisions, particularly in cases involving collective negotiations and issues of fairness of treatment of requests.

The model follows *if-then* logic—*if* certain conditions are met, *then* certain actions will automatically result. The table is established in a matrix format and facilitates the management of information and decision making. The best application of decision logic tables is to determine whether specific organizational goals and objectives are being met. Again, the school business administrator needs to be specific as to the objectives, the conditions and the alternative courses of action and state these in performance terms.

There are three primary forms of decision logic tables applicable to school organizations: the limited entry point table, the extended entry table, and the most popular mixed entry point table. They are described using a specific example and illustrated in Tables 7:2-4.

For example, using a limited entry point table, the issue facing the school business administrator is the selection of a contractor to provide a specific service to the organization. There are two relevant antecedent conditions: 1) demonstrated capability to perform the task through prior work; and 2) labor costs of the contractor. There are three possible actions that might be taken for each prospective contractor: 1) approve the contractor, 2) reject the contractor, or 3) award part of the contract to the contractor. There are only four states of nature in this example, noted as either Y(es) or N(o) in the table. The "X" in the action category denotes the action taken by the decision maker. The example demonstrates that the decision maker must follow specific guidelines designed to promote effective decisions and demonstrate consistency and impartiality. The criteria for the incomplete award are missing. This aspect of the table can be dealt with by having the decision maker refer to the second table, as indicated by the asterisk and the footnote, which permits additional conditions to be established and, on being met, return to the primary table for the final decision.

Table 7:2 Contractor Awarding

Conditions	States of Nature			
Prior Work	Y	Y	N	N
Labor Costs	Y	N	Y*	N
Actions				
Approve	X			
Reject		X		X
Incomplete Award			X	

*Refer to Table 7:3 for incomplete awards.

A second type of decision logic table is the extended entry table. This table accommodates additional conditions, usually of a more specific nature, and permits a more detailed examination of the states of nature within the organization than the limited entry type. An extension of Table 7:2 includes specific criteria for prior work experience is found in Table 7:3.

Table 7:3 Contractor Awarding

Conditions	States of Nature			
Prior Work	Y	Y	N	Y
Costs Below specs	Y	N		N
Costs on specific items below specs			Y	
Actions				
Approve	X			
Reject		X		X
Incomplete Award			X	

Table 7:3 explains the incomplete award for subcontracting work but does not account for possible increased costs due to oversight responsibilities of the school business administrator.

The last form decision logic table is the mixed entry table. Here various conditions are balanced against various states of nature. The following table deals with a set of decisions that personnel need to make regarding district funding of professional development trips. The set of conditions includes cost, and whether the trip should be related to individual job goals. The states of nature consist of three circumstances under which a staff member might attend such a function: as a willing participant, as an attendee without the responsibilities, or as a unwilling participant ordered to attend by the district. The possible actions include: approval of the trip, rejection of the trip, or partial payment for the trip to a limit specified in the policy. The various states of nature, or types of requests for professional development travel money and the resulting conditions that the school business administrator might use to render the decision are shown in Table 7:4.

Table 7:4 Professional Development Travel

	States of Nature											
	Participant				Attendee				District			
	1	2	3	4	5	6	7	8	9	10	11	12
Conditions												
Job Target Related	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Cost >$300	Y	Y			Y	Y			Y	Y		
Cost <$300			Y	Y			Y	Y			Y	Y
Actions												
Approval	X		X						X	X	X	X
Rejection				X		X	X	X				
Incomplete		X			X							
Payment*												

*Payment to a limit of 60% of the total cost.

Mathematical Techniques

School patrons, school board members, staff and the community at large are all demanding the best from each of their institutions, and the schools are no exception. Although sound intuitive reasoning may still prevail in certain decision situations, the public is demanding solutions that ensure *optimum* use of resources. School district personnel often must defend their decisions with hard data.

Mathematical techniques are used with increasing frequency by school business administrators to provide this kind of data. Such techniques attempt to quantify various aspects of the problem and then solve for the optimal solution. This is markedly different from satisfying or selecting the first best solution. The use of these techniques permits the application of some criteria of effectiveness and efficiency which permits either the maximization of return or the minimization of cost, subject to various external or internal constraints.

Again it should be stressed that solutions derived from the use of mathematical techniques are not absolute nor do they guarantee success. The school business administrator uses these techniques as "tools" to generate information which will increase the likelihood of effective and efficient decisions. Optimal, feasible solutions notwithstanding, they still need to be examined in light of the specifics of the local situation, including the goals and objectives of the district.

Linear Programming

One of the major concerns today for school business administrators is that of resource allocation. The goal is to allocate resources in such a manner as to maximize opportunities and/or minimize costs. The school business administrator is concerned with getting the most out of increasingly scarce resources. Resource allocation must be carried out within the context of specific district-wide, school or program goals and legal and fiscal constraints under which the district, school or program operates. This is a problem which involves linear programming.

Linear programming calls for the school business administrator to define in a linear fashion: 1) the various aspects of a problem (objective); 2) their relation to each other; and 3) the constraints under which they must operate. Some basic rules must be observed for the proper use of this technique.

First, each linear program problem must have something to be optimized, and this must be expressed as a linear equation. A linear equation provides for the conditions or variables under which the problem may be solved. This is called the *Objective Function* and has as its major role the delineation of a specific end result that the school business administrator has in mind. For example, if we wished to maximize achievement on the part of students, we might write the equation as follows:

Maximize Z Achievement

This would be the objective function and the desired goal of the school business administrator. It should be pointed out that the objective function now contains the letter "Z." Once the objective is established, it is common practice in linear programming to use this letter to denote the objective rather than maintaining verbiage.

Second, each linear programming problem must contain a set of variables that are part of the optimum solution. In the example above, the variables which might affect the solution to the student achievement problem are: time on task, resources and allocated instructional time. These variables must also be part of the objective function as well as be able to be expressed as linear equations. Thus, our objective function now includes:

Max Achievement = time on task (x1) + resources (x2) + allocated time (x3).

Third, the linear programming problem must also contain the constraints that limit the optimal solution. These are attached to the variables and are part of the entire program. These constraints are the limits beyond which the school business administrator may not go. They may be either less than or equal to ($<=$), greater than or equal to ($>=$), or equal to ($=$). The constraints are associated with the variables and are on the right side of the equations. These are the conditions to which the maximization of achievement are *Subject To.*

Finally, the linear programming problem must account for *Non-negativity* of the variables. As we can have no less than 0 input of each of the variables, we must account for these. Typically this non-negativity function is written as a separate statement, with the variables being either $<=$, $>=$, or $=$ to 0.

Our full linear programming problem for the maximization of achievement would look like the following and includes the use of the universal letter Z to denote the objective function.

Max Z (Achievement) = X1 + X2 + X3
Subject to:

X1	$>= 3$
X2	$<= 110$
X3	$<= 6$
x1, x2, x3	$>= 0$

What we have said in the above problem is that we wish to maximize achievement given the three *decision* variables of time on task (X1), resources (X2), and allocated instructional time (X3). We have specified the constraints as: three hours

of time on the task per day, $1 10 per day per child for academic instruction, and six hours each day of allocated time for school learning. There can be a mixture of greater than, less than, or equal to in any of the equations, but the school business administrator is cautioned to avoid an unbounded solution or infeasible solution.

With the problem set in linear terms, the school business administrator is in a position to solve for the optimal feasible solution. Since there are a variety of solutions, many of which may be feasible, we are concerned with the *optimal* feasible solution. Computer programs for microcomputers overcome the mathematical complexities easily and quickly and generate a readily recognizable optimal feasible solution. The difficult tasks are related to the establishment of the problem, the teasing out of the objective function, the variables, the constraints, and the coefficients associated with each of the variables.

Applying Linear Programming—An Example

The school lunch program, which is typically a major concern of school business administrators in terms of quality and costs, will be used as an example for examining the applications of the linear programming technique in school decision making.

A school business administrator has been approached by the representatives of the high school student council with a proposal to increase the lunch fare to include not only the typical class A lunch, but also a salad bar and an à la carte lunch. The representatives have gathered information from the student body which numbers 1,000 and found that students are likely to participate in such a program. This is gratifying as the current lunch count for the high school is 500 class A lunches, and staff is not being utilized to its fullest.

The school business administrator has asked for time to investigate the problem by testing different types of lunches and pricing/cost structures to determine the menu which will produce and maximize returns. Using the linear programming technique, the school business administrator determines that the *Objective Function* is to maximize total return. The three *Decision Variables* are the three types of lunches—class A, salad bar and á la carte.

An estimate of the number of lunches that should not be exceeded in each of these categories was determined and these become the constraints of the problem (the right hand side of the problem). Last, the costs associated with each of the lunch types is determined to be $.95 for class A, $.90 for salad bar and $.98 for á la carte. These costs are part of the objective function but are balanced with the pricing structure of $1.10, $.95 and $1.15 for each of the lunches respectively. These latter figures become the coefficients in the constraints. We can now write the linear programming problem as follows.

Min Z = .95$x1$ + .9$x2$ + .98$x3$

Subject to:

1.10$x1$	> = 400
.95$x2$	> = 100
1.15$x3$	> = 200
$x1$, $x2$, $x3$	> = 0

The Computer in Solving the Problem. After the standard form of the problem is established, the optimal solution can be determined with the help of a computer. The particular program, and succeeding computer programs, were adapted for a TRS-80 from Bui's work.[9] In using the program, the school business administrator

must answer the questions as presented, hence the need for a complete understanding of the problem before attempting to solve it on the computer. Tables 7:5-7:10 simulate the computer response.

Table 7:5 Entry Data

Linear Programming

ECONOMIC FUNCTION:
MAXIMIZE OR MINIMIZE (MAX/MIN) ? MAX
NUMBER OF DECISION VARIABLES ? 3

NUMBER OF CONSTRAINTS
(EXCLUDING NONNEGATIVITY CONSTRAINTS):
LESS THAN OR EQUAL TO ? 3
GREATER THAN OR EQUAL TO ? 0
EQUAL ? 0

DEFINITION OF VARIABLE INDICES:

DECISION VARIABLE 1 = X(1)
DECISION VARIABLE 2 = X(2)
DECISION VARIABLE 3 = X(3)

PRESS THE -SPACE BAR- TO CONTINUE . . .

SLACK VARIABLES(S) OF LESS-THAN-OR-EQUAL-TO CONSTRAINTS:
CONSTRAINT 1 = X(4)
CONSTRAINT 2 = X(5)
CONSTRAINT 3 = X(6)
COEFFICIENTS OF THE OBJECTIVE FUNCTION:
COEFF. OF DECISION VARIABLE 1 ? .95
COEFF. OF DECISION VARIABLE 2 ? .9
COEFF. OF DECISION VARIABLE 3 ? .98

VALUE OF THE RIGHT SIDE
OF CONSTRAINT 1 ? 400
VALUE OF THE RIGHT SIDE
OF CONSTRAINT 2 ? 100
VALUE OF THE RIGHT SIDE
OF CONSTRAINT 3 ? 200

Table 7:6 Entry Data

CONSTRAINT COEFFICIENTS:
COEFFICIENT OF CONSTRAINT # 1
—DECISION VARIABLE 1 ? 1.10
—DECISION VARIABLE 2 ? 0
—DECISION VARIABLE 3 ? 0
COEFFICIENT OF CONSTRAINT # 2
—DECISION VARIABLE 1 ? 0
—DECISION VARIABLE 2 ? .9
—DECISION VARIABLE 3 ? 0
COEFFICIENT OF CONSTRAINT # 3
—DECISION VARIABLE 1 ? 0
—DECISION VARIABLE 2 ? 0
—DECISION VARIABLE 3 ? 1.15

Iteration 0

BASIC VARIABLES	VALUE
X(4)	400
X(5)	100
X(6)	200

VARIABLES OF THE SIMPLEX TABLEAU
((4), X(5), X(6), X(1), X(2), X(3),
PUSH THE -SPACE BAR- TO CONTINUE

MATRIX OF COEFFICIENT A(I,J):

1	0	0	1.1	0	0
0	1	0	0	.9	0
0	0	1	0	0	1.15

MARGINAL PROFIT COEFFICIENTS Z(J)-C(J):

0	0	0	.95	.9	.98

ECONOMIC FUNCTION Z = 0

CONTINUE (Y = YES, N = NO) ? Y

Table 7:7 Iteration #1

Iteration 1

BASIC VARIABLES	VALUE
X(4)	400
X(5)	100
X(3)	173.913

VARIABLES OF THE SIMPLEX TABLEAU
X(4), X(5), X(6), X(1), X(2), X(3),

PUSH THE -SPACE BAR- TO CONTINUE

MATRIX OF COEFFICIENT A(I,J):

1	0	0	1.1	0	0
0	1	0	0	.9	0
0	0	.87	0	0	1

MARGINAL PROFIT COEFFICIENTS Z(J)-C(J):

0	0	-.85	.95	.9	0

ECONOMIC FUNCTION Z = -170.435

CONTINUE (Y = YES, N = NO) ? Y

Table 7:8 Iteration #2

Iteration 2

BASIC VARIABLES	VALUE
X(1)	363.636
X(5)	100
X(3)	173.913

VARIABLES OF THE SIMPLEX TABLEAU
X(4), X(5), X(6), X(1), X(2), X(3),

PUSH THE -SPACE BAR- TO CONTINUE . . .

MATRIX OF COEFFICIENT A(I,J):

.91	0	0	1	0	0
0	1	0	0	.9	0
0	0	.87	0	0	1

MARGINAL PROFIT COEFFICIENTS Z(J)-C(J):

-.86	0	-.85	0	.9	0

ECONOMIC FUNCTION Z = -515.889

CONTINUE (Y = YES, N = NO) ? Y

Table 7:9 Iteration #3

Iteration 3

BASIC VARIABLES	VALUE
X(1)	363.636
X(2)	111.111
X(3)	173.913

VARIABLES OF THE SIMPLEX TABLEAU
X(4), X(5), X(6), X(1), X(2), X(3),

PUSH THE -SPACE BAR- TO CONTINUE . . .

MATRIX OF COEFFICIENT A(I,J):

.91	0	0	1	0	0
0	1.11	0	0	1	0
0	0	.87	0	0	1

MARGINAL PROFIT COEFFICIENTS Z(J)-C(J):

-.86	-1	-.85	0	0	0

ECONOMIC FUNCTION Z = -615.889

CONTINUE (Y = YES, N = NO) ? Y

Table 7:10 Final Tableau

DECISION VARIABLE	VALUE
X(1) =	363.636
X(2) =	111.111
X(3) =	173.913

NOTE: ALL VARIABLES NOT SHOWN IN THIS TABLE HAVE VALUES OF ZERO

MAXIMUM Z = 615.889

*** OPTIMAL SOLUTION FOUND ***
*** AFTER 4 ITERATIONS ***
PUSH THE -SPACE BAR- TO SEE THE OPTIMAL SOLUTION . . .

When using this program the school business administrator must assign only those items that have been outlined in the problem stated. Extraneous variables associated with linear programming such as slack, surplus and artificial variables are automatically accounted for by the computer program. The *slack variables*, as needed within the example, are variables added to the left hand side of the less than or equal to constraint equations to permit the variable to become an equality. The

surplus variables are those that are subtracted from the left hand side of the equation to permit the greater than or equal to constraint to become an equality. *Artificial variables* are those that have no meaning in the problem but enable a basic feasible solution to be rendered. A slack variable is similar to the surplus variable but comes into existence where less than or equal to variables are part of the problem.

As may be seen by the optimal results produced by the program, the maximum Z is $615.889 per day return and the additional information provided by the program permits the school business administrator to establish optimum number of lunch types to be produced. It should be obvious that if costs could be reduced, prices increased and number of lunches increased, then a better allocation of resources would be provided with a further maximization of returns.

Although not an elaborate problem, the various parts found within the example demonstrate the degree to which the linear programming problem solving technique can be used. Further, the example demonstrates the efficiency with which information can be produced to enhance the business administrator's decision-making power.

Decision Making Under Risk

Whereas linear programming provides the school business administrator with a means to resolve problems, the emphasis on management decisions in the future will be to resolve problems in times of uncertainty. Every school district faces social, political and economic conditions of uncertainty. Strategic management techniques can help school managers meet the demands of the constituents by forecasting problems before they occur and planning for the risks and uncertainties.

Risk is an important consideration in decision-making process. There are basically two types of management styles with regard to risk—risk avoiders and risk takers. Risk avoiders are most typically found in education given its relatively stable and predictable political and economic environment. Evidence, however, is building that risk is becoming a way of life for the school environment as well and school business administrators need to know how to deal with it.

The risk taker is not an individual who takes risks without considering the consequences. While it may appear that the risk taker is one who blindly trusts that things will work out for the best, in reality the risk taker spends a great deal of time trying to reduce the risk involved in decision making. This is accomplished through the use of probability. Based on intuitive judgment or past experience the risk taker assigns various levels of probability to the alternatives facing the organization, and then proceeds to use these probabilities to reduce risk in selecting the optimal decision for the organization.

In examining the various alternatives, the school business administrator must consider the consequences of selecting a particular course of action and the alternatives that affect that choice. In the area of uncertainty in decision making, the use of a sequential decision-making process is a major part of the decision theory concept. The use of this process provides for a step-by-step analysis of the alternatives, with attendant probabilities and costs, and provides a model for the evaluation of risks prior to expending resources. Such an approach provides for a system-

atic analysis of the problem including all variables that affect the outcome. The various alternatives, costs and probabilities associated with the choices are put into a mathematical form. Much as with other decision-making models, data are collected on the relative frequency and strength of the various alternatives, and the model is examined frequently with changed input until the optimal solution is found.

There are two types of analytical procedures in accounting for risk and uncertainty in decision making. The first, or *Monte Carlo* technique is used in situations where there is a past history of the probability distribution which can generate events to test alternatives. The second technique, known as *Decision Trees*, is more appropriate when no history of past occurrence is available on which to base probabilities. This technique calls on the school business administrator to use formal intuitive processes to estimate the probabilities associated with the occurrences of various alternatives that affect the choice of the optimal decision.

Decision Tree Approach

In using the decision tree approach, the school business administrator analyzes the individual alternatives in relation to the decision alternatives. The following steps are involved in the process:

1. The school business administrator lists all alternative decision possibilities for the resolution of the problem.
2. The school business administrator determines all alternative events (states of nature) that might result from the selection of all the alternatives.
3. The school business administrator reviews the events and assigns the best estimated probability to each event. The estimated probability denotes the probable occurrence of the events and focuses attention on the impact of that alternative event on the final and total decision.
4. The school business administrator outlines all outcomes and assigns probabilities to all the possible outcomes.
5. The school business administrator evaluates the consequence of each alternative according to criteria established. Typically this is done by evaluation based on expected monetary value (or maximum return on the use of resources) or expected opportunity loss (the cost of not making the decision).
6. The school business administrator then returns to the initial decision point(s) and evaluates these by weighing each consequence of the various courses of action by the probability estimates assigned to the alternatives.

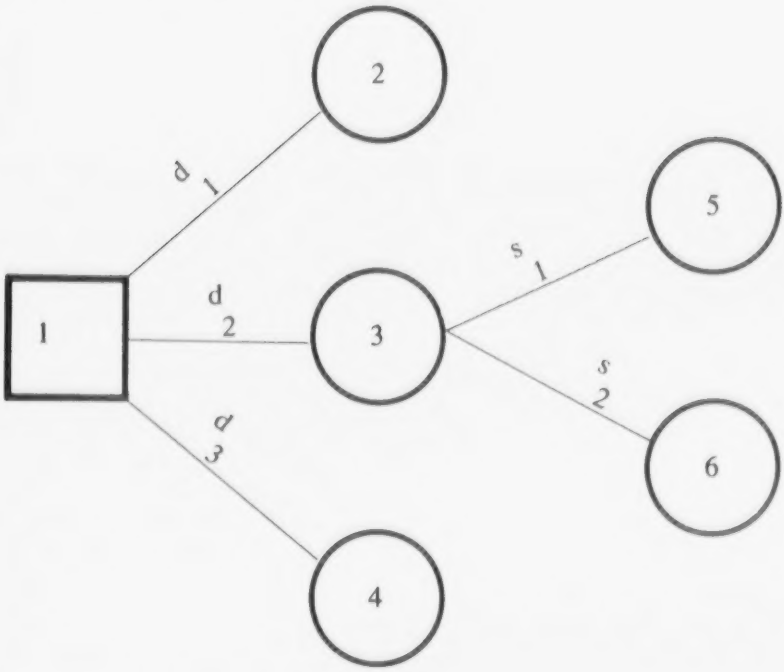
In building the decision tree, the school business administrator is concerned with the decision points (called "nodes" represented by squares) where the decisions are to be made, and alternatives (denoted as "branches" represented by lines among the different points in the tree). The school business administrator starts at the nodes and follows the branches until an examination has been completed for all possible alternatives in the various states of nature. Where a branch leaves the decision node, it is called a decision branch and carries no probability. When the branch leaves a state of nature or alternative condition node (indicated by circles), the branch is called a state of nature branch. All nodes and branches are numbered consecutively beginning with the initial decision node. Decision branches are denoted as "d," and state of nature branches are labelled "s," with appropriate subscripts to keep the various branches identifiable.

Figure 7:1 reflects the use of nodes and branches. Decision point node #1 is the final decision in this example. Branches d1, d2, and d3 are the possible alternatives that the school business administrator faces. Nodes 2, 3, and 4 are states of nature nodes (as denoted by the circle) and the branches s1 and s2 identify the various outcomes from that state of nature.

Once the decision tree has been drawn, the school business administrator enters the appropriate information pertinent to each branch—costs and probabilities—and computes the gain or loss. The final task is to select one decision node based on the probability estimates that provides the least cost or the greatest gain. This gain or loss is associated with the expected monetary value (EMV). To obtain this value the EMV for each alternative must be computed and entered allowing the school business administrator the widest range of choices. The EMV is the sum of the weighted payoffs for each alternative. The weight in this case is the probability estimate assigned by the individual for each of the various states of nature.

Application of the Decision Tree Approach—An Example. To demonstrate the use of the Decision Tree let us say, for example, that a school district has received a grant for $31,000 for the sole purpose of purchasing microcomputers for the high school. An initial review of the systems available reveals three systems might be used, but the benefactor has stipulated that: 1) one system alone must be purchased, and 2) that the district receive maximum use of the system selected. Included in the decision process is the cost of initial in-service training of the staff at a cost of $3,000. The alternative to this cost is a bill for $2,000 for traditional in-service training. The in-service needs to be addressed prior to the use of the microcomputer systems and the outcome of the program affects the use of the system selected. A major consideration is the number of machines that might be purchased for the money. System A yields sixteen machines but has limited software.

Figure 7:1 Decision Tree—General Form



System B yields twelve machines and has software applicable to some, but not all academic programs. System C yields ten machines and has some software currently available, with more being developed. The school business administrator conducts a cursory survey of the staff at the high school and finds that the microcomputers would be used approximately twenty-five periods per week, if there were high acceptance of the concept, and sixteen periods per week, if there were low acceptance. These figures were then applied to the total cost ($31,000) and yielded a high acceptance per unit cost of $1,240 for each of the machines and a low acceptance per unit costs of $1,937. Using this information, the school business administrator constructed Table 7:11 including costs and estimated probabilities. See Figure 7:2 for the decision tree diagram.

Table 7:11 Decision Alternatives

d1	In-service for microcomputers	$3000
d2	General in-service program	$2000
d3	Micro system #1	$31000
d4	Micro system #2	$31000
d5	Micro system #3	$31000
d6	Negative in-service results	$3000

States of Nature		Cost	Probability
s1	Positive in-service	$0000	.64
s2	Negative in-service	$0000	.34
s3	High use of System #1	$1240	.55
s4	Low use of System #1	$1937	.45
s5	High use of System #2	$1240	.6
s6	Low use of System #2	$1937	.4
s7	High use of System #3	$1240	.7
s8	Low use of System #3	$1937	.3

In the diagram we have denoted costs with a minus sign, as we are looking for the expected monetary value (EMV) for the least cost. In resolving the issues and examining the alternatives, the school business administrator begins on the right hand side of the tree and computes the EMV for each alternative. This is done by multiplying the cost factor by the estimated probability. Adding the sums produced yields the EMV for each level and provides the school business administrator with the data needed to select the optimal alternative or the best decision.

While this example, and similar small problems, can be calculated by hand, the use of microcomputer programs for decision tree analysis facilitates the process and is essential for larger problems with many alternatives and states of nature. Using the decision tree model computer program and the data given, a printout of the results of this decision tree appears in Tables 7:12-15.

Table 7:12 Decision Tree Entry Format

Decision Tree

ADJUSTMENT FOR PRESENT VALUE
YES (1) OR NO (0) ? 0

NUMBER OF BRANCHES ? 14

Branch #1:

NUMBER OF 'FROM' NODE ? 1
NUMBER OF 'TO' NODE ? 2
PROBABILITY ? 0
ESTIMATED OUTCOME (IN $) ? -3000.

Figure 7:2 Decision Tree Illustration

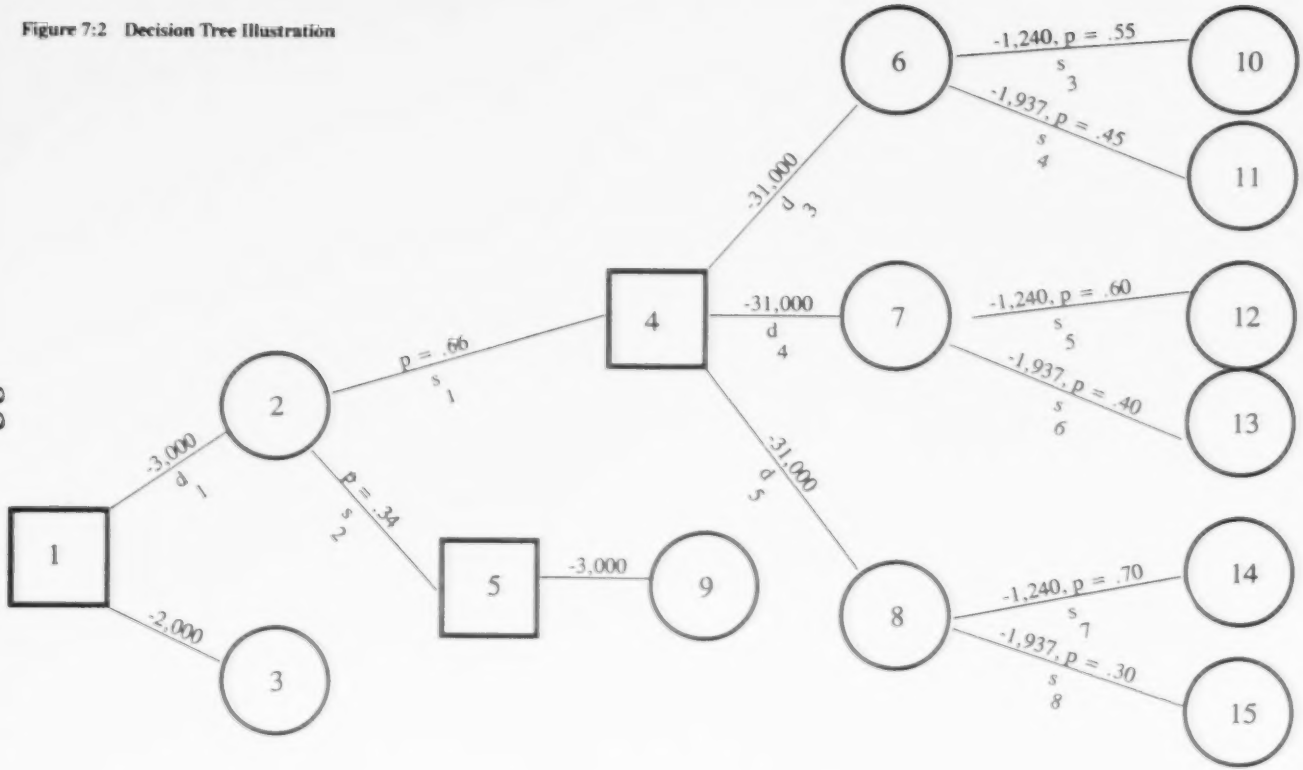


Table 7:13 Decision Tree Sorted Data

Sorted Decision Tree Table

SOURCE	DEST	PROB	PERIODS	DOLLARS
1	2	0	0	-3000
1	3	0	0	-2000
2	4	.66	0	0
2	5	.34	0	0
4	6	0	0	-31000
4	7	0	0	-31000
4	8	0	0	-31000
5	9	0	0	-3000
6	10	.55	0	-1240
6	11	.45	0	-1937
7	12	.6	0	-1240
7	13	.4	0	-1937
8	14	.7	0	-1240
8	15	.3	0	-1937

CONTINUE ? Y.

Table 7:14 Evaluation of Sorted Data

Evaluation of the Decision Tree

SOURCE	DEST	PROB	PERIODS	DOLLARS
1	2	DECISION	0	-3000
1	3	DECISION	0	-2000
2	4	.66	0	0
2	5	.34	0	0
4	6	DECISION	0	-32553.7
4	7	DECISION	0	-32518.8
4	8	DECISION	0	-32449.1
5	9	DECISION	0	-3000
6	10	.55	0	-682
6	11	.45	0	-871.65
7	12	.6	0	-744
7	13	.4	0	-774.8
8	14	.7	0	-868
8	15	.3	0	-581.1

CONTINUE ? Y

Table 7:15 Optimal Decision

Optimal Decisions Retained

SOURCE	DEST	ESTIMATED RESULTS
1	3	$-2000
4	8	$-32449.1
5	9	$-3000

NOTE: THIS TABLE SHOWS THE BEST DECISION FOR EACH LEVEL OF THE DECISION TREE.

As indicated in Table 7:12, the information is provided by entering data as requested in the format provided. Table 7:13 indicates the information pertinent to the problem in a manner that permits the school business administrator to check for errors of entry. Table 7:14 reports the computed EMV for each level based on the cost factor and the probability estimates provided by the school business administrator. Table 7:15 provides the school business administrator with a record of the

optimal decisions to be considered. In the example, decision nodes 1-3 and 5-9 are considered, as they represent least cost at specific points within the program. If the school business administrator chose to follow the general in-service program route, then the cost would have been only $2,000 and not the $3,000 as indicated in decision 1-2. Decision 5-9 indicates to the school business administrator that if a negative response to the microcomputer in-service program warranted discontinuance of the microcomputer program, the cost would be the $3,000. Of special interest is decision 4-8. Although it represents the least number of machines purchased based on the estimated probability of high and low acceptance and use of the microcomputer systems under consideration, this decision branch, with the attendant states of nature and perceived outcomes, yielded the best choice or return on the investment.

While the example provided is small, it demonstrates the use of microcomputer programs for decision trees as a powerful technique in the school business administrator's arsenal of combating risk and uncertainty in the decision-making process. The data for decisions are based on quantification of information, and the use of a quantitative technique provides only data which are applicable to enhance the decision-making process. It is still the responsibility of the school business administrator to make the final choice as to the decision from the various alternatives. This choice needs to be made in light of the goals and objectives that the district has established.

Inventory Control Using a Deterministic Model

While curricular and non-curricular programs can be eliminated, personnel reduced-in-force and major savings instituted through drastic measures, the fulfillment of the district's teaching-learning objectives must not be damaged. It is not always the costly budget items that reduce the effective use of the district's revenues. The district can lose operating effectiveness through the cumulative effect of seemingly minor expenses that total sizable sums. Thus, a means must be found to contain the smaller cost items that reduce the effectiveness and efficiency of the business function. Whereas we have examined complex issues and techniques in quantitative decision making, the following procedure will permit the school business administrator to gain control of costs and, at the same time, ensure that adequate materials and supplies are on hand to fulfill the objectives of the district.

There is both a need in the fiscal management of the district to provide logistical support for programs and personnel and to reduce costs. The district management can control costs while still providing for the completion of tasks by instructional and support personnel within the district, through judicious and rational control of inventories.

Fear of running short is inherent to all materials and supply handling. Nevertheless, a greater need is to contain costs while guarding against "stockouts" that would detract from the effectiveness of school operation. The very nature of school districts, as stable organizations with relatively constant demands for supplies and materials, permits the use of the inventory control/management technique called *Economic Order Quantity (EOQ)*. EOQ is a model that assists the school business administrator in determining the reorder policy for the organization while at the same time maintaining the lowest cost to the organization. It is a "deterministic

model," as it is based on the past history of the demand for the item by the district. The inventory technique seeks to: 1) reduce costs, 2) have the item available for use, and 3) optimize the meeting of objectives by the organization. The questions that inventory control seeks to answer are: 1) how much to order? 2) when to order? and 3) how to reduce costs?

There are two separate sets of costs involved within the inventory control process—*ordering costs* and *holding costs*. Ordering costs involve all the costs associated with placing one order of the item, regardless of the size of the order. Included in ordering costs are secretarial time, computer time, stationary, stamps, bidding process and time for approval. Holding costs include such items as cost of storage facilities, labor costs for redistribution, utilities, insurance, general administrative costs of maintaining the item on the inventory and keeping track of the unused portion of the item, and the interest lost to the organization by using the funds rather than leaving them in an interest-bearing account.

The first step in the process of using EOQ is for the school business administrator to determine the demand for the item within a time frame useful for the organization. For school district management accustomed to bidding items on a once-a-year basis, the yearly demand is most suitable. Once the demand for the item is established, the school business administrator can begin to determine the costs involved in securing and holding the item.

The ordering cost is relatively easy to establish. As indicated, it is the total cost of all the aspects contained in ordering the item. The ordering cost is a function of the number of orders placed within the given time period, and not the quantity of the item ordered. Once the ordering cost is determined, it is entered into the following formula used in determining the annual ordering cost for the item.

$$(D/Q)\,Co$$

where

D = demand for the item over the time period

Q = quantity ordered per order period

Co = cost of each order.

The holding costs, complete with the entire range of factors that make up the costs, is typically figured using a percentage of the price of the item on a per unit basis. Once the holding cost per item has been determined, the school business administrator enters the cost into the following formula to calculate the annual holding cost for the entire time unit. The formula for annual holding costs is:

$$\tfrac{1}{2}\,QCh$$

where

Q = the quantity ordered for the order period

Ch = the holding cost (percent of the unit price).

The formula uses one-half Q as a base for determining holding costs. Since the inventory is drawn up on during each time period, whether one year or one month, the costs of holding the items in stock for the first half of the period are offset by the costs of holding the stock for the second half of the time period.

With these two costs determined, the next step is to calculate the total annual cost for the inventory. The formula for this is:

$$TC = \tfrac{1}{2}\,QCh + (D/Q)\,Co$$

This formula represents a combination of the ordering cost and holding cost formulas.

Although the school business administrator may know the demand (D) for the item for the time period, and the cost (both ordering and holding), missing in the formula is the quantity represented by the letter Q. Thus, the school business administrator constructs a table showing ranges of quantities which can reasonably be ordered and the resultant calculations of annual holding costs, ordering costs and total costs. This is a trial-and-error method of finding the lowest total cost (TC) which still meets the needs of the organization. Once the table has been constructed with inspection of the total costs, the school business administrator can select the optimum quantity to order.

There is, however, a second means by which to determine the optimum minimum quantity to be ordered. By using the following formula, the school business administrator can determine the minimum order that will optimize the cost. The formula is:

$$Q = \sqrt{\frac{2DCo}{Ch}}$$

where

D = demand for the item during the time period
Co = ordering costs
Ch = holding costs

The quantity rendered by the formula consistent with the costs involved is the optimum quantity.

As with all management science techniques, the data generated should serve as merely a guide for the school business administrator in the decision-making process. It is the amount of inventory that should be ordered to minimize costs.

The school business administrator still needs to know the *reorder point* and the *cycle for ordering* the items. The reorder point is the level that the school business administrator must not go below prior to reordering in order to avoid a stockout and disruption of services. This reorder point is determined using the following formula:

$$r = (d)\,(m)$$

where

r = the reorder point
d = the daily demand for the item
m = the lead time for processing and receiving the order from the supplier

The other item needed for effective and efficient control over the inventory of the district is the cycle of reordering which can be found by using the following formula:

$$T = \frac{365Q}{D}$$

where

Q = quantity ordered per time period

D = total demand for the item

The yield for this formula is the number of days between orders.

Applying the Deterministic Model to Inventory Control—An Example

The following example will demonstrate the use of the formulas presented above to the decision-making process related to inventory. A school district is faced with the need to be more effective and efficient within the management of the district. School board members are demanding closer control of all cost areas. While they have examined program curtailment and reduction-in-force of personnel, they are also scrutinizing the excess costs of the district and are seeking better control in all areas of district fiscal operations. Board members who have backgrounds in business operations have asked for a better means of inventory control. They are concerned with the large amount of paper that is purchased on bid on a once-a-year basis and then held at various locations within the district. More than one location is used due to the lack of a central storage facility, thus incurring additional holding costs. They have asked the school business administrator to examine this issue and render a report as to a purchase policy to insure maximum use of the item and minimization of costs.

The school business administrator has surveyed school and central office personnel for paper needs on a yearly basis. There has been an examination of the past orders of the district and there is consistency in both use and ordering. The total demand for the paper is set at 7,000 reams per year (or 3.5 million sheets of paper per year). The cost of a ream of paper on the bidding process has stabilized at $2.65 per ream. The cost of a single order, regardless of the quantity of paper ordered, has been determined to be $9.14 per order. After a survey of the storage facilities, the holding costs, which include inventory control and the cost of redistributing paper to individual schools, have been set at 13 percent of the per unit price, or $.344 per ream. The school business administrator determines that the quantity schedule for ordering might be as follows: 7,000, 6,000, 5,000, 4,000, 3,000, 2,000, 1,000, 500, 250. Using the formulas as set forth, the school business administrator constructs Table 7:16 to demonstrate the costs for each order size.

Table 7:16 Order Quantity And Costs

Order Quantity	Annual Holding Costs	Annual Ordering Cost	Annual Total Cost
7000	$2408	$ 9.14	$2417.14
6000	2064	10.66	2074.66
5000	1720	12.79	1732.79
4000	1376	15.99	1391.99
3000	1032	21.32	1053.32
2000	688	31.99	719.99
1000	344	63.98	407.98
500	172	127.96	299.96
250	86	255.92	341.92

The dollar amounts are found by substituting the figures given in the Total Cost formula. For example,

TC = .344 (7000) + 7000/7000 (9.14)
which yields holding costs of $2408, ordering costs of $9.14, for a Total Cost of $2417.14 for a one time order and holding of 7000 reams of paper.

The costs incurred as listed are only holding and ordering costs and do not include the actual cost of the paper at $2.65 per ream. This cost of the item must be considered and the total cost for each level of quantity order completed. These costs do not affect the EOQ model for optimization of the order and minimization of the costs, since the overall cost of the item will remain constant throughout the entire time period.

By inspection, the school business administrator can see that to provide the continuous flow of paper for the district at the lowest cost, the economic order quantity (Q) is 500 reams per order. The use of this order quantity would yield a significant reduction in costs of 87 percent. However, this is merely a rough approximation of the needs and cost minimization process. What would be the optimum order quantity? Using the formula for

$$Q = \sqrt{\frac{2(7000)\,(9.14)}{.344}}$$

optimization a more accurate figure for order quantity and costs is determined. Six hundred and nine yield the following costs:

Annual holding costs = $209.49

Annual ordering costs = $105.07

Annual Total Costs = $314.56.
This optimization yields a reduction in costs of 86 percent as compared to the current practice of one order of 7,000 reams per year.

The reorder point, using the formula given, is

r = (9589) (5) or 95.89 reams of paper.

The reorder cycle, using the formula given, is

T = 365(609)/7000 or 31.75 days between orders with a total number of orders set at 11.496.

Although the calculations can be completed by hand, the school business administrator can quickly calculate the same information easily and efficiently with a computer program. Moreover, the program is able to incorporate the effects of limited storage capacity on the quantity ordered and the associated costs. The program has been completed twice, once with no storage limitations (see Table 7:17) and once with a limitation of 500 reams (see Table 7:18) to show the differential in costs and reorder cycle.

Table 7:17 EOQ With Optimization

Optimal Inventory Management

ANNUAL DEMAND FOR ITEM (IN UNITS) ? 7000
PRICE: NO REDUCTION (0), ONE REDUCTION (1), TWO REDUCTIONS (2) ? 0
UNIT PRICE OF PRODUCT ? 2.65
COST OF ONE ORDER ? 9.14
UNIT HOLDING COSTS: (PERCENT OF PURCHASE PRICE) ? 13
SHORTAGE COSTS ? 0
LIMITED INVENTORY CAPACITY: YES (1), NO (0) ? 0.

RESULTS OF THE EOQ MODEL:

OPTIMAL ORDER QUANTITY = 609 UNITS.
UNIT PURCHASE PRICE = $ 2.65.
TOTAL INVENTORY COSTS = $18760.
TOTAL INVENTORY COSTS = $18865.1

ORDERS SHOULD BE PLACED 11.5 TIMES PER YEAR.

Table 7:18 EOQ With Limited Storage Space

Optimal Inventory Management

ANNUAL DEMAND FOR ITEM (IN UNITS) ? 7000
PRICE: NO REDUCTION (0), ONE REDUCTION (1), TWO REDUCTIONS (2) ? 0
UNIT PRICE OF PRODUCT ? 2.65
COST OF ONE ORDER ? 9.14
UNIT HOLDING COSTS: (PERCENT OF PURCHASE PRICE) ? 13
SHORTAGE COSTS ? 0
LIMITED INVENTORY CAPACITY: YES (1), NO (0) ? 1
MAXIMUM CAPACITY OF INVENTORY ? 500

Results of the EOQ Model:

OPTIMAL ORDER QUANTITY = 609 UNITS.
UNIT PURCHASE PRICE = $ 2.65.
TOTAL HOLDING COSTS = $18760.
TOTAL INVENTORY COSTS = $18865.1

ORDERS SHOULD BE PLACED 11.5 TIMES PER YEAR.

INVENTORY CAPACITY IS LESS THAN OPTIMAL
WITH LIMITED INVENTORY CAPACITY . . .

RESULTS OF THE EOQ MODEL:

OPTIMAL ORDER QUANTITY = 500 UNITS.
UNIT PURCHASE PRICE = $ 2.65.
TOTAL HOLDING COSTS = $18764.1.
TOTAL INVENTORY COSTS = $18892.1

ORDERS SHOULD BE PLACED 14 TIMES PER YEAR.

COSTS DUE TO LIMITED CAPACITY = $4.13

*** OPTIMAL QUANTITY = MAXIMUM CAPACITY

Multiple Criteria Decision Making

Up to this point we have concerned ourselves with optimization of resources based on single criteria or sets of values. In reality, school districts operate in an environment which creates demands from a variety of stakeholders and attempts to meet the needs of many diverse individuals and groups. Where once the concept of finding the first solution that answers the question or solves the problem worked for school management personnel, the recurrent demands for effectiveness requires school administrative personnel to optimize their decisions and search for the single best alternative from the many that face them.

Today, the school administrator is afforded the opportunity to move from the reactive stance of traditional not-for-profit organizations to a stance of entrepreneurial management and adopt techniques that will permit the optimization of alternatives to problems.[10] Yet, in the optimization for cost effectiveness, the school business administrator must retain efficiency in operation. With efficiency as a goal, the administrator must be concerned with selecting the best alternative to meet organizational objectives, while at the same time maintain cost benefit. The move toward efficiency offers a plethora of alternatives which take into consideration the diverse goals and objectives of various groups that make up the environment of the school district—pupils, parents, community members, teachers and staff, and administrative and board personnel.

The administrator needs a means by which to reduce this diversity to a reasonable level to permit proactive decisions supportive of the district's programs. *Multi Criteria Decision Making (MCDM)* is a quantitative decision-making tool, which permits various groups to deal with qualitative issues of programmatic goals and objectives. This technique goes beyond the maximization of effectiveness or the minimization of costs. It also includes accounting for the subjective and objective judgments of individuals involved in the decision-making process using a weighted format. It is a particularly viable technique for decision making when faced with a variety of complex and conflicting issues and a significant number of alternatives that must be considerred. The MCDM process permits a uniform and consistent analysis of the various alternatives and analysis of the effect that the alternatives present to the decision-making situation. Useful at various levels of decision making, it fosters openness in the district's efforts to achieve long-term goals and objectives. For instance, use of the technique in the long-range planning process might well begin with each subgroup (teachers, parents, students and advisory committees of the board). It would then analyze each of the alternative goals and objectives and render a composite decision regarding the specific priority for the alternatives under consideration.

The process for completing the MCDM technique follows specific steps. Although it is a relatively simple technique from a mathematical standpoint, substantial effort is required in the reaching of consensus on the criteria, attributes, weights and values that are included within the process. The procedures are outlined as follows:

Step One. A decision needs to be rendered regarding the applicability of the problem to the MCDM techniques. As with any technique discussed, not all problems are amenable to the technique. Problems most suitable to the MCDM process are those that have a number of alternative choices that would permit the optimization

of the goal or objective. Second, a problem is suitable for MCDM if there are a number of criteria that can be applied to the process for analyzing the choices and rendering a decision.

Step Two. The alternatives from which the final decision will be made must be selected. It is important that only those alternatives that are feasible and can be implemented be considered.

Step Three. The school business administrator lists the criteria on which the alternatives will be evaluated. The criteria are the specific values associated with each of the items. For example, if the alternatives were salary schedules for staff, criteria might include the dollar limit per step or the perceived effectiveness of the salary schedule in recruitment and retention of personnel.

Step Four. Within the process of establishing criteria, the school business administrator provides a listing of the attributes or measures that will be used to determine the value of each of the criteria for each alternative. For example, if one criteria were usefulness, the attribute might be the ease of operation for staff and students.

Step Five. The school business administrator ranks each of the alternatives based on the criteria provided given the attributes that have been established. These are then added together and the total divided by the number of criteria in order to arrive at an average value of each of the alternatives.

Step Six. To account for the subjective evaluation of each of the alternatives, a weight is assigned to the different criteria. This assignment of weight is separate from the ranking process described in step five. This step provides for the various groups to reach consensus on the value of each of the criteria and provides the district administrator with agreement across partisan lines as to the value each groups places on the criteria.

Step Seven. The final step in the MCDM process provides for a final ranking for each of the alternatives. This is accomplished by multiplying the ranking for each criteria with each alternative and summing the score. This yields a final ranking that provides data for the school business administrator to use in rendering the final decision on the choice of alternatives. In many instances there will be a change in the ranking for each of the alternatives due to the weights or values placed on each of the criteria. This is the portion of the MCDM process that permits the subjective value judgment of each individual group to become part of the process.

The MCDM process provides for the selection of the best alternative given the constraints and priorities of various groups within the district. Further, it permits the district management personnel to open the channels of communication with the various segments of the community and to involve them in the district's movement toward a proactive stance regarding education.

Applying MCDM—An Example

A school district is faced with a common problem—a number of vocal interest groups concerned the selection of materials designed to meet the educational goals and objectives of the district. The selection process must take into consideration

the meet and confer agreement that the district made with staff involved with curriculum and instruction.

The district is faced with a relatively simple problem—that of selecting textbooks for reading at the elementary level. There are a number of reading series available, but the district is under increasing pressure to select a series that *best* meets criteria related to fulfilling the objectives of the reading program. Thus cost effectiveness is not the primary concern. The administration's challenge is how to incorporate the opinions of various interest groups (parents, staff and students) in order to maximize the reading performance of their students.

Table 7:19 shows the established criteria using the MCDM model.

Table 7:19 Criterion and Attributes

Criteria	*Attributes*
C1 — Usefulness	Level of meeting goals and objectives of the district
C2 — Readability	Score from Readability formula
C3 — Interest Level	Score of Interest formula
C4 — Cost of item	$ cost per unit
C5 — Inservice demands	$ cost for inservice

The criteria need to be established by all groups involved in the decision-making process, and the attributes understood so that proper ranking of the alternatives can be accomplished.

Next, as shown in Table 7:20, the various groups decide the value of the rankings for each of the alternatives based on each of the criteria.

Table 7:20 Value of Rankings

Usability and Cost for District	Value (points)
Outstanding/Low Cost	9 — 10 points
Above Average/Below Average Cost	7 — 8 points
Average/Average Cost	5 — 6 points
Below Average/Above Average Cost	3 — 4 points
Unusable/High Cost	1 — 2 points

Once the criteria, attributes and value for each criteria have been established, the school business administrator lists the ranking for each of the alternatives on each of the criteria. This is done in tabular form as follows:

Table 7:21 Decision Matrix I

	C1	C2	C3	C4	C5	Average
A1	10	6	8	7	3	6.8
A2	8	7	9	6	4	6.8
A3	7	9	6	6	3	6.2
A4	9	5	7	7	4	6.4

Although this table provides the school business administrator with a means to render a decision regarding alternatives one through four, the table does not consider the weight or value each of the criteria have within the decision-making process. Thus, a listing of the weighted values for each criteria is needed in order to produce a final ranking. These weights are as follows:

Table 7:22 Value of Weights for Final Ranking

Ranking	*Weight*
Extremely important	5
Very important	4
Important	3
Slightly important	2
Minimally important	1

Table 7:23 Decision Matrix II—Final Weighted Average Criterion

	C1	C2	C3	C4	C5	Weighted
Weight	(5)	(5)	(4)	(2)	(1)	Total
Alternative						
A1	50	30	32	14	3	129
A2	40	35	36	12	2	127
A3	35	45	24	12	3	119
A4	45	25	28	14	4	116

The school business administrator can use these weights in determining the final weighted value for each of the alternatives on each criteria and produce the final weighted total.

In the end it is still the school business administrator who must make the decision. Nevertheless, the MCDM process generated pertinent data, including opinions and judgments from important sectors of the school district, which not only facilitate the decision-making process, but also secure the implementation process.

NOTES

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